Changes in land cover and fire risk associated with nonnative grass invasion in Hawaii

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Background

- It is generally accepted that the synergistic effects of fire and grass invasion have led to conversion from forest to grassland throughout the tropics (Figs 1 and 2)
- Little data is available to support this conversion on a landscape scale in Hawaii.
- If true, nonnative grasslands are more flammable than forests due to changes in fuel loads and microclimate thus at increased risk of fire occurrence and spread.

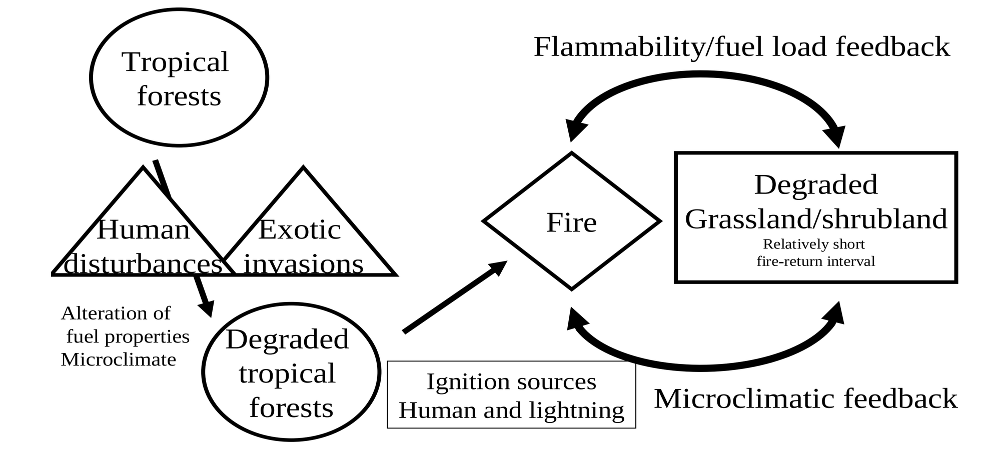


Fig. 1. Nonnative grass and reoccurring wildfire have significantly altered dry and moist life zones in Hawaii. D'Antonio and Vitousek 1992

Fig. 2. Historical change in Makua Valley (leeward Oahu) over the past 35 years. Repeated fires have shifted plant composition towards a fire-prone, nonnative grass dominated landscape.

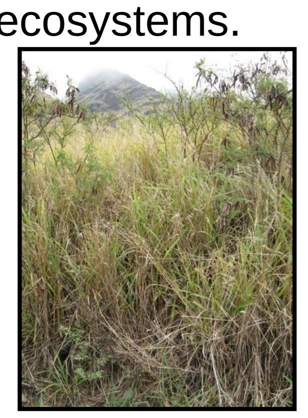
Objectives

1. Measure the rate and extent of land cover change from 1950-2011 in and around two heavily managed areas at Schofield Barracks and Makua Military Reservation on Oahu, Hawaii.
2. Use field data and modeling to examine differences in potential fire behavior in forests and grasslands

Methods

•Fuel loads, fuel height, and live and dead fuel moisture were measured in forest and nonnative invasive grass (*Megathyrsus maximus*) plots (*n*=6) in the Waianae Kai Forest Reserve and Dillingham Airfield.

•These field data were then used to parameterize the BehavePlus fire modeling program to predict potential fire behavior (flame length, rate of spread, fireline intensity) in forest vs. nonnative invasive grass ecosystems.



BehavePlus for fire behavior modeling

•Predicts fire behavior in wildland fuels
•Used during fires for real-time predictions of fire behavior or in prescribed fire planning

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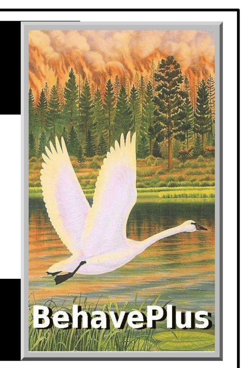


Historical imagery (1950-2011) was used to quantify the rates of change in land cover

- Orthorectified and georeferenced
- Digitized into polygon shapefiles using ArcGIS. Each site was divided into two areas of interest (AOI): a grassland area within the fire break which is heavily utilized for military training activities and a forested area outside the fire break, where little military activity occurs.
- *Create Fishnet* tool was used to divide the study sites into grids with a 50 x 50 m cell size
- Land cover in each cell was classified into cover classes: Grass, shrub, forest, bare, developed, military training area (MTA), and shadow/cloud (treated as No Data)

Results: Land Cover Change

- Increased grass in heavily managed areas at both Makua (320 ha) and Schofield (745 ha) at rates of 2.62 and 1.83 ha yr^{-1}, respectively. (Figs 3-6)
- More rapid rates of conversion before aggressive fire management practices were implemented in the early 1990's.
- At Makua, conversion from forest to grassland in the surrounding landscape (1244 ha) was slower (1.78 ha yr^{-1}) than in the managed area (Figs 3-4)
- Outside the managed area at Schofield (1576 ha), nonnative woody plants reestablished into grasslands at a rate of 4.75 ha yr^{-1} (Figs 5-6)

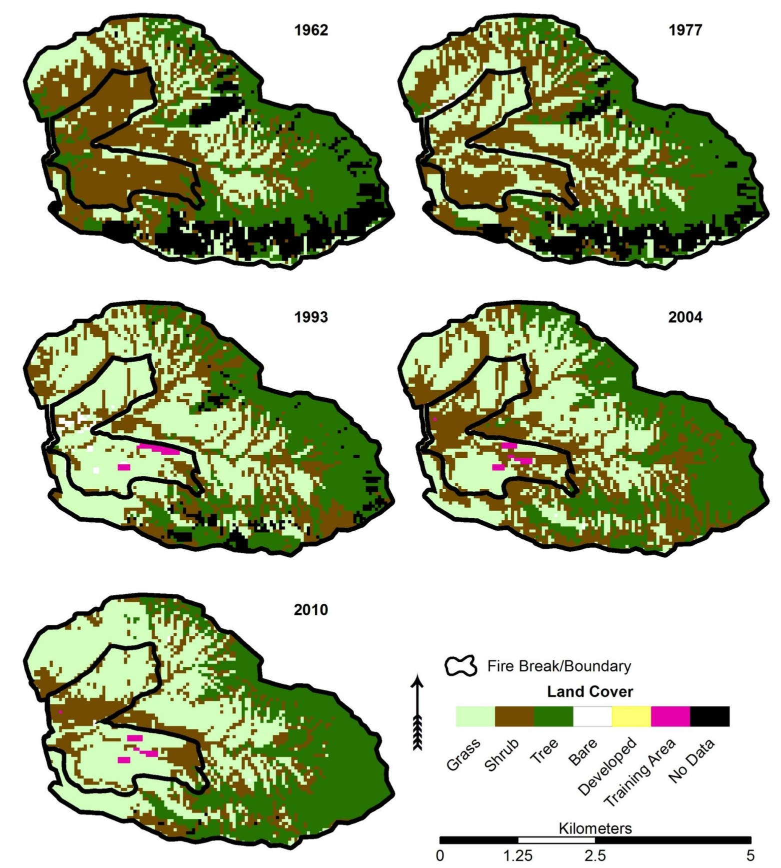


Fig. 3. Land cover at Makua Military Reservation on leeward Oahu, Hawaii from 1962 through 2010. The area inside the firebreak is heavily utilized for military training activities, and fire is frequent. The area outside the firebreak has historically been forested, has many threatened and endangered species, and is impacted to a lesser extent by military activities and fire.

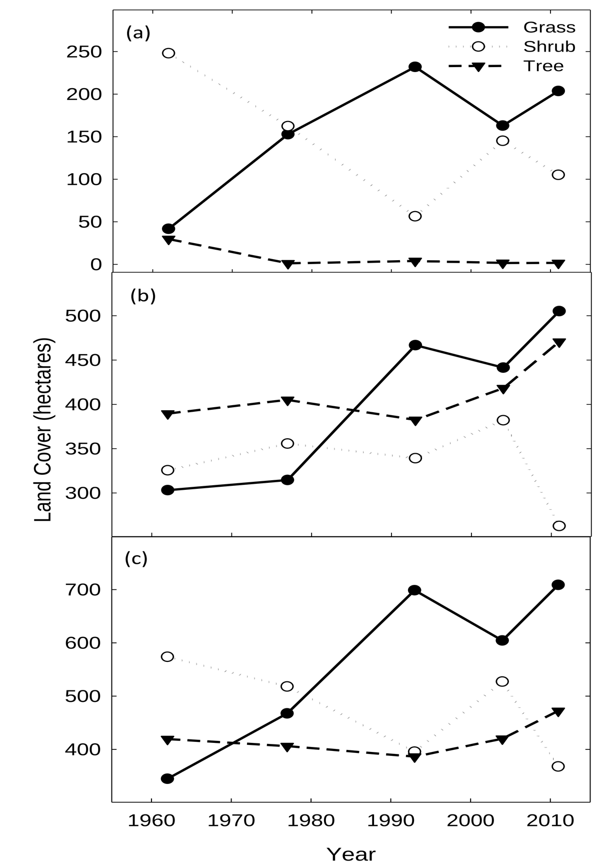


Fig. 4. Change in grass, woody, and military training area land cover classes from 1962-2011 at Makua Military Reservation. Areas of interest (AIO) include: a) heavily utilized grassland area inside firebreak, b) nonnative forest area outside firebreak, c) the entire Makua complex (both AOI's combined).

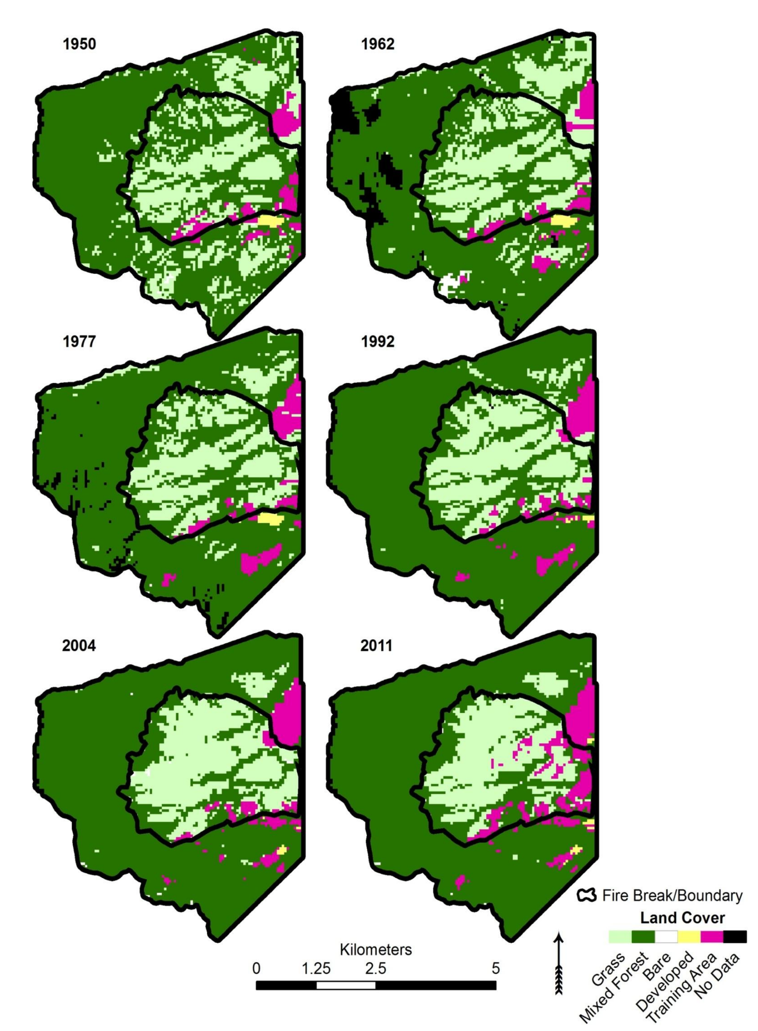


Fig. 5. Land cover at Schofield Barracks on leeward Oahu, Hawaii from 1950 through 2011. The area inside the firebreak is heavily utilized for military training activities, and fire is frequent. The area outside the firebreak is maintained for woody species, and is less affected by military activity and fire.

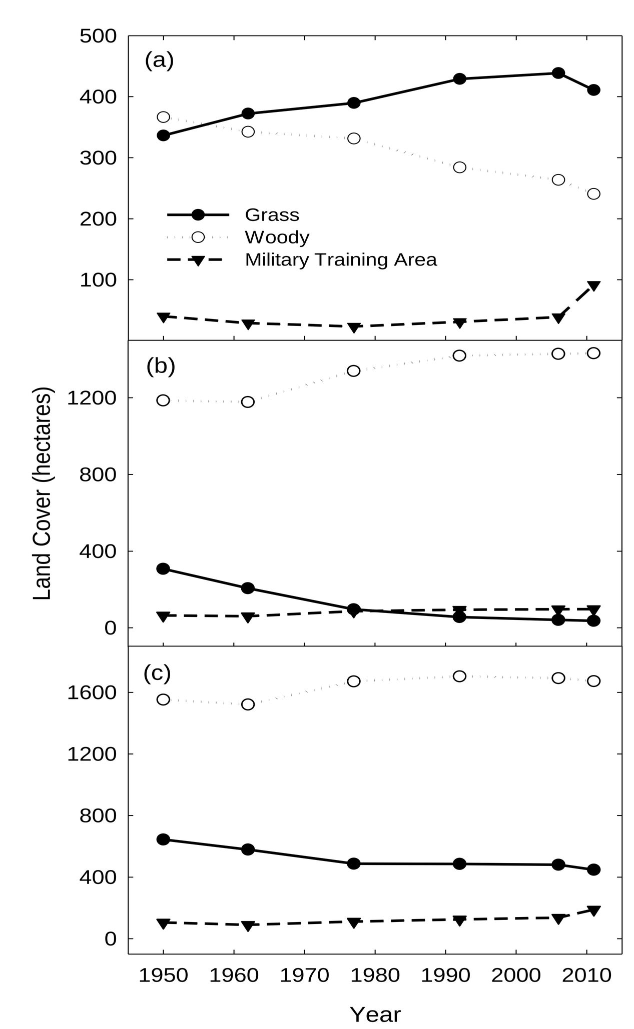


Fig. 6. Change in grass, woody, and military training area land cover classes from 1950-2011 at Schofield Barracks. Areas of interest (AIO) include: a) heavily utilized grassland area inside firebreak, b) nonnative forest area outside firebreak, and c) the entire Schofield Barracks complex (both AOI's combined).

Results: Fuels and Fire Behavior

- Live and dead fuel moisture and fine fuel loads did not differ between forests and grasslands (Table 1)
- Mean fuel height was lower in forests (72 cm) than in grasslands (105 cm; *P*=02) (Table 1)
- Rate of spread was higher in grasslands (5.0 to 36.3 m min^{-1}) than forests (0 to 10.5 m min^{-1}) (*P*<0.001) (Table 2)
- Flame lengths were higher in grasslands (2.8-10.0 m) than in forests (0-4.3 m; *P*<0.01) (Table 2)

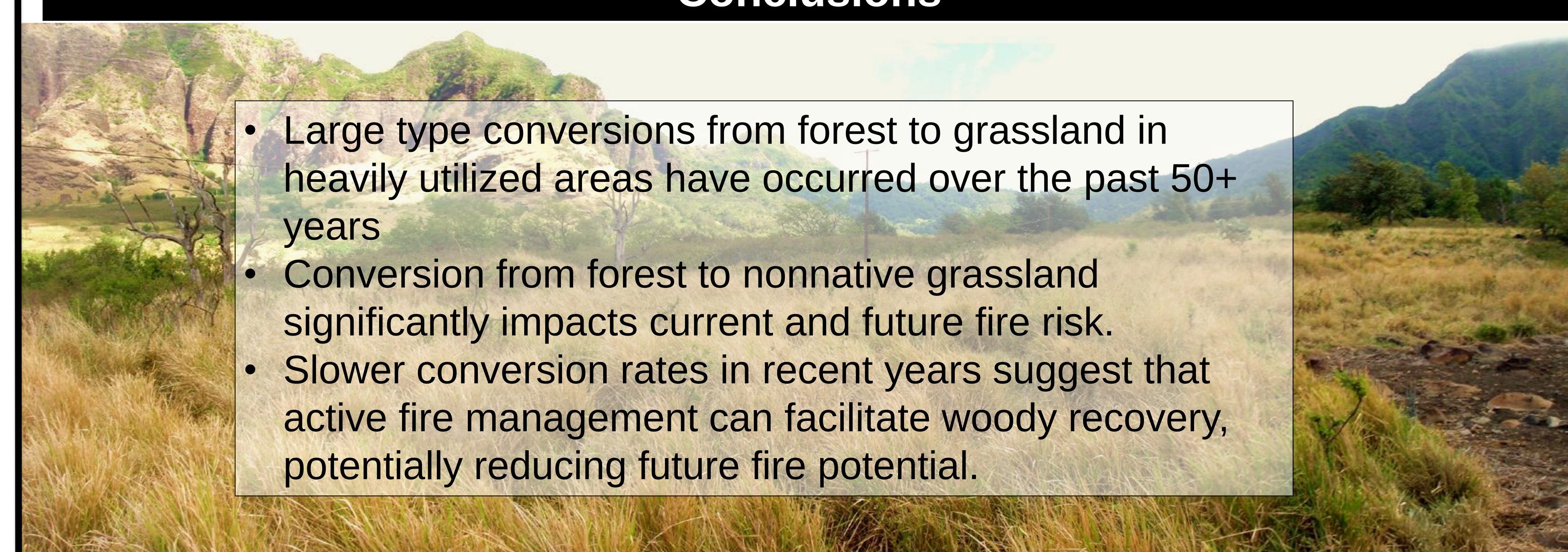
Table 1. Live and dead fine fuel loads (in Mg ha^{-1}), fuel moisture (%), and maximum fuel height (cm) in open guinea grass ecosystems and forested ecosystems with a guinea grass understory on leeward Oahu, Hawaii. Means and standard errors are given for fuels variables at each site (N=3). Significant model factors are indicated by bold font.

Variable	Dillingham Grass	Dillingham Forest	Waianae Kai Grass	Waianae Kai Forest	Model R^2 (%)	MAP	Site (*P*-value)	Type
live fine fuels	4.6 (0.9)	5.9 (3.9)	3.7 (0.4)	2.1 (1.0)	31.08	0.38	0.65	0.86
dead fine fuels	19.5 (4.3)	19.5 (3.0)	13.7 (0.6)	10.4 (1.8)	51.36	0.52	0.80	0.89
live fuel moisture	47.2 (3.6)	78.2 (13.1)	57.7 (9.0)	173.6 (27.3)	84.22	**0.02**	0.18	0.19
dead fuel moisture	13.6 (2.3)	23.4 (6.8)	15.5 (2.9)	65.2 (31.4)	61.70	**0.05**	0.14	0.95
max. fuel height	138.6 (9.7)	71.0 (3.0)	71.3 (10.7)	72.3 (12.0)	76.46	**0.02**	**<0.01**	**<0.01**

Table 2. Predicted fire behavior under both moderate (15 kph) and severe (30 kph) wind conditions in open guinea grass ecosystems and forested ecosystems with a guinea grass understory on leeward Oahu, Hawaii. Means and standard errors are given for fire behavior parameters at each site (*N*=3). Significant model parameters are indicated by bold font.

Variable	Wind condition	Dillingham Grass	Dillingham Forest	Waianae Kai Grass	Waianae Kai Forest	Model R^2 (%)	MAP	Site (*P*-value)	Type
Rate of Spread	moderate	14.93 (1.56)	2.70 (1.23)	5.87 (0.59)	0.40 (0.40)	90.97	**0.04**	**<0.01**	**<0.001**
(m min^{-1})	severe	30.73 (3.10)	5.67 (2.58)	12.03 (1.22)	0.83 (0.83)	91.07	**0.04**	**<0.01**	**<0.001**
Flame Length	moderate	5.80 (0.98)	2.10 (0.52)	3.03 (0.23)	0.27 (0.27)	84.78	0.61	0.10	**<0.01**
(m)	severe	8.10 (1.35)	2.93 (0.78)	4.27 (0.32)	0.40 (0.40)	84.61	0.62	0.11	**<0.01**
Fireline Intensity	moderate	12829 (4075)	1503 (750)	2983 (537)	57.67 (57.67)	71.31	0.13	**0.04**	**<0.01**
(kW m^{-1})	severe	26355 (8298)	3154 (1598)	6135 (1084)	123.67 (123.67)	71.53	0.13	**0.04**	**<0.01**
Probability of	moderate	21.00 (7.00)	10 (10)	14.33 (5.55)	0.333 (0.333)	38.45	0.84	0.82	0.27
Ignition (%)	severe	21.00 (7.00)	10 (10)	14.33 (5.55)	0.333 (0.333)	38.45	0.84	0.82	0.27

Conclusions



- Large type conversions from forest to grassland in heavily utilized areas have occurred over the past 50+ years
- Conversion from forest to nonnative grassland significantly impacts current and future fire risk.
- Slower conversion rates in recent years suggest that active fire management can facilitate woody recovery, potentially reducing future fire potential.

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